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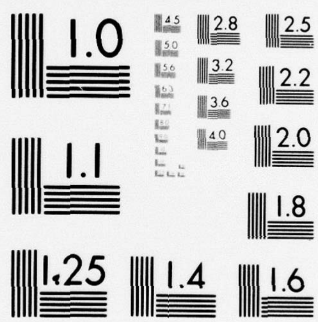

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AIR FORCE AVIONICS LABORATORY

APPLICATION OF THE RCA PRICE-S SOFTWARE COST ESTIMATION MODEL TO AIR FORCE AVIONICS LABORATORY PROGRAMS

AVIONICS SYSTEMS ENGINEERING BRANCH
SYSTEMS AVIONICS DIVISION

OCTOBER 1979

TECHNICAL REPORT AFAL-TR-79-1164
Final Report for period January 1978 – July 1979

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This technical report has been reviewed and is approved for publication.

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FOR THE COMMANDER

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 AFAL-TR-79-1164	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 Application of the RCA PRICE-S Software Cost Estimation Model to Air Force Avionics Laboratory Programs, Revision.		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report. Jan 78 — Jul 79
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 Capt Thomas G. James, Jr. USAF Mr Daniel V. Ferens		8. CONTRACT OR GRANT NUMBER(s) 16 2003, 6095
9. PERFORMING ORGANIZATION NAME AND ADDRESS System Evaluation Group Avionic Systems Engineering Branch (AFAL/AAA) Wright-Patterson AFB, OH 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62204F/2003/09/02 12 51
11. CONTROLLING OFFICE NAME AND ADDRESS System Evaluation Group Avionic Systems Engineering Branch (AFAL/AAA) Wright-Patterson AFB, OH 45433		12. REPORT DATE 11 Oct 1979
		13. NUMBER OF PAGES 48
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 17 09, 15		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

62204F

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Software
cost
model
avionics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers work conducted in-house by the System Evaluation Group (AAA-3), Avionic Systems Engineering Branch, Air Force Avionics Laboratory, Wright-Patterson AFB, Ohio 45433. This work was a calibration and validation of the proprietary RCA Corporation PRICE-S software development cost model to four AFAL software programs. The results of the study are that PRICE-S appears to work well for Air Force Avionics Laboratory programs and more validation/calibration studies should be done.

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FOREWORD

This report is a revision of AFAL-TM-78-25, which covers work conducted in-house by the System Evaluation Group (AAA-3), Avionic Systems Engineering Branch, and the Reference Systems Branch, Air Force Avionics Laboratory, Wright-Patterson AFB, Ohio, 45433. Portions of this work were accomplished under Task 200309, "Avionics System Cost-Effectiveness," Work Unit 20030902, "Avionics Life Cycle Cost," and Work Unit 60951502, "Cost Estimating Methodology." The time period of work was November 1977 through August 1978.

Great appreciation is extended to Mr Earl J. Jones, Mr William Mikulski, Mr William E. Shephard, and Mr R. Vanderburgh for their assistance and contributions to this report.

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I. INTRODUCTION

BACKGROUND

In a recent USAF study of information processing requirements it was shown that in almost all applications, computer software was the major source of difficult problems, a major contributor to operational performance penalties, and potentially the largest source of life cycle cost.[1] The Deputy Assistant Secretary of Defense (Material Acquisition) estimated in 1976 that the DOD annually expends three billion dollars for computer software.[2] Although avionics software is only ten percent of the estimated distribution of USAF software costs, this amounts to still a sizable annual expenditure for computer software associated with avionics programs. In addition to the constantly rising cost for software development, software reliability, unresponsiveness, and indirect costs associated with slippages in software developments are of major concern to the USAF. As a result, the Air Force is taking a closer look at software development procedures and a greater portion of its R&D resources are being allocated to the software verification and validation (V&V) and to software development tools. However, in order to reduce the costs of software, the Air Force requires a defined method which will allow the analyst, software engineer, or project manager to estimate software development and support costs when the basic requirements of the new system being developed can be determined. Operations analysts and software professionals have developed methods and procedures for understanding software systems and how to develop these systems. Examples of this type of work is evident in a report

ASD-TR-76-11, Management Guide to Avionics Software Acquisition, and AFAL-TR-77-66, Software Cost Estimating Methodology. Although these kind of studies do exist and tools and techniques required to develop software systems have been developed, the system software manager responsible for the development of the software project has not possessed the ability to accurately estimate the costs associated with such a development. The consequences to the software developers and customers are dramatic as a result of the failure to develop accurate cost estimating techniques. Several key decisions depend on timely, accurate cost estimates such as: source selection decisions, system design trade-off analysis, project scheduling and capital budgeting decisions.[2] The Avionics Laboratory has investigated the use of "software cost estimating models" such as the Wolverton model, Modified Wolverton model, ESD model, the Tecolote model, the IBM model, Naval Air Development Center model, Aerospace model, General Research Corporation model, and the System Development Corporation model. The majority of the models were either of the "rule of thumb" type or of parametric estimating relationships based on very limited amounts of data. Each model was designed for a particular application, but the Avionics Laboratory study concluded that there was no generalized model that could be applied to a variety of software development efforts.

During the middle 1970's, the Air Force Avionics Laboratory started to utilize the RCA Corporation's Programmed Review of Information for Costing and Evaluation (PRICE) family of cost predicting models. The Avionics Laboratory first utilized the basic PRICE model (referred to now as PRICE-H), which predicts development and production costs for proposed electromechanical devices or systems while they are still in

the conceptual stage. The PRICE model has been in development at RCA for the last fifteen years. Although the detailed workings of the PRICE model are proprietary, the model has been available for general use outside RCA via time sharing services since August 1975. In May 1977 the Air Force Avionics Laboratory was introduced to the RCA PRICE Software Model, referred to now as PRICE-S. This introduction consisted of a two-day training course held at Moorestown, New Jersey, by RCA Corporation. PRICE-S applies the PRICE parametric modeling methods to the problems of computer software development costing and is designed to cover the complete range of systems and applications programming. This report describes an AFAL effort to validate and calibrate the RCA PRICE-S model for avionics software development programs within the Air Force Avionics Laboratory. As is apparent to any one familiar with the PRICE models, quantitative inputs, (e.g., for hardware, physical parameters like weight, volume, etc., or for the software, total number of instructions, hardware configuration, and mixture of categories of instructions) together with selected subjective inputs are utilized to derive the final cost estimate. These subjective inputs are so sensitive that for the PRICE-H and PRICE-S models the user can derive any cost he wishes. The problem faced by the user and/or cost analyst is to calibrate required subjective inputs which reflect the situation for which the estimate is being developed; that is, he must get a feel for the required subjective inputs which will obtain an accurate estimate of the project. This study was conducted to help the analyst obtain such a feeling, and to provide future guidance for calibrating the subjective inputs required for the PRICE-S model.

OBJECTIVE

This report describes the efforts to validate and calibrate the PRICE-S model by comparing the costs computed by the model to the actual costs of four software development programs within the Air Force Avionics Laboratory. The approach used was first to identify software development programs on which there was historical cost information for the software developed. Once the programs were identified, the cost analyst and the software engineer gathered the required inputs to the PRICE-S model. The cost analyst then utilized those inputs, plus the subjective inputs derived from experience and the RCA PRICE-S reference manual's guidance to obtain an estimate of total development cost. The outputs from the PRICE-S model were then compared to the historical costs gathered under step one of this procedure. It is worth noting at this point that except for the first project analyzed (GEANS), the historical costs were not furnished to the cost analyst in advance of the utilization of the model so that the results could not be biased in any manner.

SUMMARY OF RESULTS

As mentioned above, four software development efforts within the Air Force Avionics Laboratory were chosen for this analysis. The first project was the in-house conversion of the Gimballed Electrostatic Gyro Navigation System (GEANS) software from a Honeywell HDC-601 computer to the Singer-Kearfott SKC-2000. The second project was another in-house effort referred to as the in-house simulator program named LINEAR. LINEAR represents the behavior of a linearized error model of a 3-axis inertial navigation system through the simultaneous solution of a set

of seven first order differential equations by rectangular integration. The last two efforts are contractual efforts which include a radar project and an antenna project. In the cost of these two projects actual historical costs are as of this date yet unknown, and the cost used in the analysis to compare with the outputed RCA PRICE-S estimate was the planned program funding.

The data base selected for this analysis included a representative sample of software development projects from the standpoint of two being in-house and two being contracted efforts. There is also a range in program size from 2600 to 73750 machine language instructions. This adds to the confidence that the model is versatile in these respects. The results are summarized below in Table 1.

PROJECT NAME	PRICE-S ESTIMATE	ACTUAL COST	% DIFFERENCE
GEANS	$406,035	$425,000	5% (-)
IN-HOUSE SIMULATOR	12,039	12,000	0.3% (+)
ANTENNA	143,746	128,000	13% (+)
RADAR	1,890,922	2,000,000	5% (-)

TABLE 1. PRICE-S Estimated vs. Actual Costs.

Except for the GEANS project, the PRICE-S value or estimate is the figure derived by the cost analyst working without prior knowledge of the actual cost. The subjective inputs, which will be discussed in Appendix A of this report, were not derived in a vacuum for this analysis. The RCA PRICE-S manual was used as a reference and

these subjective inputs were then calibrated downward in most cases due to previous experience on other applications of PRICE-S. Two of the fundamental findings of this report are: first, the PRICE-S model seems to work quite well for avionics software developments efforts; and second, the average subjective inputs are much lower than stated in the RCA PRICE-S reference manual. These two findings will be discussed further in the Analysis Section of this report.

II. WHAT PRICE-S IS

BACKGROUND

PRICE-S is a software development cost and schedule estimation model developed by RCA Corporation. It is based on parametric modeling methods that were used to develop their highly successful PRICE Hardware model for hardware cost and schedule estimations. The model is versatile; it allows the user to tailor the methods and regressions to fit the varying skills, experience, and costs of specific projects and organizations. There are three modes of operation available, the normal operation, ECIRP, and the design-to-cost mode. Costs are calculated directly from user inputs for the normal operation mode. The ECIRP mode (ECIRP is PRICE spelled backwards) enables PRICE-S to be utilized to calculate PRICE-S empirical factors from known project costs. In the design-to-cost mode the model utilizes specified costs to compute typical program sizes and project schedules to scope work goals for design-to-cost efforts.

According to RCA the principle PRICE-S inputs may be grouped into seven categories.[3] The seven categories are listed below.

1. Project Magnitude - the size or the amount of work to be done.
2. Program Application - the type of project, such as Management Information System, Command and Control, Telemetry, Communications, etc.
3. Level of New Design - the amount of the effort that can be taken from existing inventory.
4. Resources - the experience, skill, know-how, and cost of the assigned individuals or team as applicable to the specified task.

5. Project Difficulty - the schedule time, in calendar months, required to complete the job with respect to the organizational resources, program application, and project size.
6. Project Specifications and Reliability - the requirements relating to testing, transportability, efficiency, and end use of the project (airborne, space, etc.).
7. Utilization - the effect of load conditions on the processor relative to its speed (operations per second) and memory (for example, is overlaying necessary?). Compiler inefficiencies may be a problem.

Rather than using the seven categories of inputs described by RCA, this report will group the inputs into three distinct categories for further discussion, those categories being: environmental parameters, hard system parameters, and soft system parameters.[2] Detailed descriptions of these parameters, as well as the parameter values selected for each project, are described in Appendix A.

a. Environmental Parameters

The environmental parameters describe the environment within which the system will be developed. These factors include such parameters as price inflation or escalation (ESC), programming technological improvement (TECIMP), and the schedule data. The schedule data is further broken down into: start of design (DSTART), end of design (DEND), implementation start date (ISTART), implementation end (IEND), test start date (TSTART), test end date (TEND), and the base year of the analysis (YEAR). These parameters permit users to vary the economic, technological and work schedules assumptions.

b. Hard Input Parameters

The hard input parameters represent system characteristics which can be physically measured. These parameters include such things as total number of executable machine instructions (INST), device types, quantity of devices, and the proportion of the total instructions that represent each of the seven different application categories. Although they may or may not be well defined at the time a cost estimate is made, historical data can be used to generate firm measures of these quantities for any system.

c. Soft Input Parameters

The soft input parameters are more subjective in nature and may require the using organizations to calibrate them to derive typical values. PRICE-S utilizes three soft parameters requiring calibration. These parameters were referred to earlier in this report as subjective inputs. Resources (RESO) is a measure of the inherent difficulty of the system development task. Theoretically, it relates the scope of the work to the shop doing the work. Included in RESO are the effects of such things as skill levels, experience, productivity, and efficiency rates. Engineering Complexity (CPLX) is a measure of how long a project should take (i.e., relates the difficulty of the task to the normal time required for its accomplishment). The parameter platform (PLTFM) is a measure of the reliability (sometimes thought of as an operational environment) required of the system. The outputs of the PRICE-S model include cost and schedule estimates. The cost estimates are broken out in matrix form. Columns of this matrix are the three phases of the software development process as defined by RCA as: (1) design; (2) imple-

mentation; and (3) test and integration. The rows are the five productive activities described by RCA as: (1) systems engineering; (2) programming; (3) configuration management; (4) documentation; and (5) program management. The output schedule estimates include beginning and end dates for each of the three phases mentioned above. Detailed outputs for the four projects analyzed are included in Appendix B.

A more detailed description of the PRICE-S model is beyond the scope of this report. More indepth information about the model can be obtained from references (3) and (4), or by contacting knowledgeable personnel in the Avionics Laboratory. PRICE-S has been implemented by a commercial time sharing organization. The Air Force Avionics Laboratory has contracted with RCA PRICE Systems, Inc., for the use of the program. The contract entitles the Avionics Laboratory to access the program by using a standard teletype terminal.

III. PROJECTS ANALYZED

PROJECT DESCRIPTIONS

The four avionics software development projects selected for this study are described in this section.

a. Project A: GEANS Software Conversion

The PRICE-S model was used to estimate development costs of the conversion of precision inertial navigation system software from the Honeywell HDC-601 Computer to the Singer-Kearfott SKC-2000. The inertial navigation system was the Gimballed Electrostatic Gyro Navigation System (GEANS) developed under AFAL contract by Honeywell, Inc. The GEANS hardware consists of an Inertial Measurement Unit (IMU), an electronics unit, a digital computer, and an associated control-and-display unit.

The purpose of the GEANS Software Conversion Project was to evaluate the machine dependency and flexibility of application of the GEANS software. This was accomplished by implementing the alignment and navigation algorithms developed originally for the Honeywell HDC-601 digital computer on the Singer-Kearfott SKC-2000. The software converted was that used for Optimized GEANS and is not identical to the more recently developed SPN/GEANS software, although differences are minor.

The conversion project was accomplished at the Air Force Avionics Laboratory (AFAL/RWA-3) by AFAL personnel using the facilities of the Reconnaissance and Weapon Delivery Division Software Evaluation Laboratory.

b. Project B: In-House Simulator Program

The simulation program is named LINEAR and represents the behavior of a linearized error model of a 3-axis Inertial Navigation System.

The program was written in FORTRAN Higher-Order Language for use on the CDC computer complex at WPAFB. It uses the SCOPE operating system and is run interactively via INTERCOM.

The mathematical approach used in this simulation program is the simultaneous solution of a set of seven first order differential equations by rectangular integration. The program contains units conversion and matrix initialization instructions and provides for plotting of the solution by Calcomp plotter.

c. Project C: Contracted Antenna System

This project consists of a phased array beam pointing antenna. It is to be used in a hostile (i.e., jamming) electronic environment to receive navigation information from an Air Force system. It is possible to steer the null point of the beam at a jamming signal, thereby minimizing the effect of the jammer while maximizing the signal from the system.

The software for this system consists of a simulation program and an adaptive algorithm. The simulation program consists of the antenna model, antenna polarization, and power levels. Output data consists of adaptive weighted values, which give amplitude and phase shift. This simulation program will be used to investigate the system anti-jam (AJ) performance and vulnerability assessments. The adaptive algorithm is the implementation of the antenna system with the software used to control it in real-time. The software will be hosted on a microprocessor.

d. Project D: Contracted Radar Program

This project consists of software for an electronic radar system. Some of the software characteristics are as follows:

Control is via a table-driven, dynamically modified executive which sequences processing under either foreground or background conditions. Processing includes navigation update, antenna pointing, and data processing for mapping and terrain modes and the control of associated input/output transfers. Both interleaved and dedicated time tests assure data and hardware integrity, and help to meet fail-safe requirements. Off-line fault detection/isolation software-controlled tests identify line-replaceable modules/units to be replaced between missions.

PRICE-S DATA PROJECTS ANALYZED

AFAL/RWA personnel assisted AFAL/AAA-3 in gathering necessary PRICE-S input data for all four projects analyzed. Values for the empirical parameters and the hard parameters were taken directly from RWA data, except for the number of instructions for the contracted antenna that had to be computed. Values for the soft parameters were estimated by the AAA-3 analyst, then approved by RWA-3 personnel. Except for project A, the AAA-3 analyst had no prior knowledge of the actual costs when he computed the soft parameters; he did not "adjust" those inputs to get the "right" costs. A detailed discussion of all input values selected for each project is given in Appendix A.

Using the input data in Appendix A, the analyst ran the PRICE-S model for each project. The outputs for each run, which are detailed in Appendix B, included the following:

a. Total costs of software development.

b. A sensitivity matrix, which shows how small changes in two soft parameters, RESO and CPLX, affect the total project cost.

c. A schedule output, which compares the input schedule with a "typical" schedule generated by the model for the same type project and outputs possible cost savings that can be realized by schedule readjustment.

IV. DISCUSSION OF OUTPUTS

PROJECT OUTPUTS

a. GEANS Software

The total cost of the GEANS Software Conversion was furnished by AFAL/RWA-3. The effort required eight and one-half man-years. Conversion to estimated industry cost was accomplished by converting at the rate of $50,000 per man-year. Thus, the total actual cost of the project was $425,000. The PRICE-S Model estimated cost, with RESO equal to 2.7 and CPLX equal to 1.00, was $406,035.

Comparing the sensitivity analysis of RESO and CPLX, the model gave a range from $378,315 to $441, 212. By the results of sensitivity data, Appendix B, values of RESO=2.8 rather than 2.7 and CPLX the same, 1.0, would result in a cost of $427,777; this indicates that values of 1.0 for CPLX and 2.8 for RESO would probably be the best for estimating the cost of similar programming tasks. Had the actual cost not been known, the analyst would have estimated a price of $406, 035 which is $19,000 too low. The percentage error would thus have been 4.5 percent. The SCHED output of the model indicates that this project could have been done in 17 months instead of 31 months at a cost savings of $71,391. This indicates possible inefficiency in use of resources and indicates that future projects of this type may be done in less time.

b. In-House Simulator

The total cost of the In-House Simulator Program was furnished by AFAL/RWA-3. The total actual cost of the project was $12,000. The PRICE-S Model estimated cost, with RESO equal to 3.15 and CPLX equal to .9, was $12,039.

Comparing the sensitivity analysis of RESO and CPLX, the model gave a range from \$11,741 to \$12,473. By the results of sensitivity data, Appendix B, the chosen values of RESO and CPLX appear to be reasonable. Hence, values of .9 for CPLX and 3.15 for RESO should probably be used for estimating the cost of similar programming tasks. The error would thus have been \$39. The SCHED output indicates that \$741 could have been saved by doing the project in 2.1 months instead of 3 months. This indicates that projects of this type may be done in shorter times.

c. Contracted Antenna

The actual total cost of the Contracted Antenna was \$128,000, which was also the total contract funding of this effort. The PRICE-S model estimated the cost of the adaptive algorithm, RESO value equal to 2.7, CPLX equal to 1.0, of \$65,249, as detailed in Appendix B. The PRICE-S model estimated \$69,366 for the simulator program, RESO equal to 2.7, CPLX equal to 1.0. The cost to integrate and test the adaptive algorithm and simulator programs together was estimated by PRICE-S at \$9,130, which results in a total cost of \$143,746. The results of the sensitivity data indicate a cost range between \$132,996 and \$152,968 with expected cost of \$143,746. The percent error would have been approximately thirteen percent using the expected value. Sensitivity data indicates that using a lower RESO and/or CPLX value would have resulted in a more accurate prediction.

A point of particular interest here is that the cost analyst does not know beforehand a particular company's mark-up value. To explain further, the value MULT in the PRICE-S model is used to adjust the

estimate to include mark-up G&A, IR&D, currency conversion and fee or profit. In this case MULT was 1060, which indicates a six percent mark-up was assumed. Assuming no mark-up, expected engineering costs for the adaptive algorithm would have totaled $135,609. Schedule data indicates that the actual schedule was not much different from the PRICE-S "typical" schedule. Only a $5,000 savings could be realized by adjusting the schedule.

Applications of the RCA PRICE-S model estimate for this type of project may be difficult. The PRICE-S model can be used to evaluate different proposals to do a certain software job, but the inputs must be accurately estimated for the proposals and the mark-up of a particular company must be known. However, the PRICE-S model does seem to be able to scope this type of effort within reasonable bounds.

d. Contracted Radar

The total cost of the Contracted Radar computer program is not known at this time, but is expected to be $2.0 million. This cost accounts for G&A, fee and profit, in-house IR&D, totalling between 11 and 12%. The PRICE-S model estimated cost with RESO equal to 2.5, CPLX equal to .9 and MULT equal to 1120 (12% mark-up), was $1,890,922, as detailed in Appendix B. If the PRICE user was confident in the choice of RESO=2.5, CPLX=.9, the cost estimator would have quoted $1,890,922. As compared to $2.0 million expected this would have been a 5% error. However, from the sensitivity analysis, RESO=2.6 would have resulted in a more accurate estimate.

A few words should be said referencing the Schedule Effect Summary. The schedule which was supplied by the Program Office required 60 months of development time. RCA PRICE model calculated a "typical schedule"

of 20.8 months, which results in a cost penalty of $700,657 for stretching the schedule. The Program Office stated that 60 months were required because consecutive hardware development precluded a faster software development schedule. The actual validity of the "typical schedules" calculated by the PRICE-S model were not addressed in this study; however, it is recommended that the effects and validity of PRICE-S schedule calculations be studied in future analysis.

The table below summarizes the analysis. The actual reported costs are shown together with the PRICE-S estimate and the RESO and CPLX value used in the analysis. Where indicated, different RESO and CPLX values would have given closer estimates, but were not known before the cost analyst was given the actual reported costs.

PROJECT	ACTUAL COST	PRICE-S	RESO	CPLX
GEANS Conversion	$425,000	$406,035	2.7	1.0
In-House Simulator	$12,000	$12,039	3.15	.9
GPS Null-Steering Antenna	$128,000	$143,746	2.7	1.0
EAR	$2,000,000	$1,890,922	2.5	.9

V. RECOMMENDATIONS

The analysis of these four software development projects allows the formulating of some general conclusions. First, the PRICE-S model seemed to work quite well in these particular efforts and therefore, should be utilized, along with engineering estimates, to obtain a preliminary cost of future software development projects. The PRICE-S user must realize that for AFAL systems, certain complexity factors such as RESO and CPLX may be lower than the "average values" stated in the PRICE-S users manual. This study is just the beginning of many analyses which must be performed before the USAF can have a 100% confidence in the results of the PRICE-S model. First, many more than four historical programs should be calibrated against the model outputs to establish a comprehensive data base of complexity factors for use during analyses of new programs. The effects of the RCA calibrated schedules should be investigated for their accuracy. The future analyses requires the use of a large and well formed data base of software development efforts, which is non-existent to date. But in the interim PRICE-S seems to be the most appropriate software cost estimation model for obtaining preliminary software cost information, which is available to the cost analysts today.

APPENDIX A

PRICE-S INPUTS

This appendix contains a detailed discussion of all inputs used for the PRICE-S model for the four projects described in this report. A generalized description of the software programs is found in Section III of this report. The last six pages of this appendix are the actual input sheets used for each project.

The reader is asked to refer to the RCA PRICE-S User's Manual for further information. AFAL System Evaluation Group has a copy and will be happy to answer questions the reader may have.

For this appendix the four projects are abbreviated as follows:

Project A: GEANS Software Conversion

Project B: In-House Simulator

Project C: Contracted Antenna

Project D: Contracted Radar

PRICE Software Model Input Worksheet

Filename: ______

Page __ of ____

Title: Appendix A: PRICE-S INPUTS

Application: ______

Date: ______

								Optional	
Descriptors	INST	APPL	RESO	FUNCT	STRU	LEVEL		INTEG	
	(1)	(2)	(3)	(4)				(5)	
Mix	MDAT	MONL	MREA	MINT	MMAT	MSTR	MOPR	MAPP	APPL
	(6)								
New Design	DDAT	DONL	DREA	DINT	DMAT	DSTR	DOPR	DAPP	
	(7)								
New Code	CDAT	CONL	CREA	CINT	CMAT	CSTR	COPR	CAPP	
	(8)								
Device Types	TDAT	TONL	TREA	TINT					
	(9)								
Quantity	QDAT	QONL	QREA	QINT					
	(10)								
Schedule Data	CPLX	DSTART	DEND	ISTART	IEND	TSTART	TEND		
	(11)	(12)							
Supplementary Information	YEAR	ESC	TECIMP	MULT	PLTFM	UTIL		TARCST	
	(13)	(14)	(15)	(16)	(17)	(18)		(19)	

Notes:

See Following pages for detailed discussion of these parameters

INPUT DESCRIPTIONS

(Refer to the PRICE-S Input Sheet, page A-2, for item number reference)

1. INST - Is the total number of machine-level executable instructions in a program. The number of instructions for Projects A, B and C were obtained directly from RWA personnel. The "$" for the Integration and Test Section of Project C indicates that portion of the project is for the cost of integration and test only; no additional instructions are involved. For Project D, the number of instructions had to be computed from number of words. It was given that the entire program consisted of 58,000 "resident" words and 60,000 "off-line" words. It was further stated that 40% of all instructions required 1 word and 60% required 2 words; hence, INST was computed as follows:

$$\text{INST} = \frac{58{,}000 + 60{,}000}{(.4 \times 1) + (.6 \times 2)} = \frac{118{,}000}{1.6} = 73{,}750$$

2. APPL - This is a single parameter which summarizes the mix of instructions. Either APPL or MIX (See #6) must be specified for all programs since all programs had a variety of applications, MIX was input instead of APPL using the MIX descriptions on Table 1.

3. RESO - This parameter relates the scope of the work to the shop doing the work, and is a single parameter which includes factors such as skill levels, productivity, labor rates, and efficiency.

The combined effect of these factors, according to RCA, tends to remain constant for a particular organization over time. RCA says, in the PRICE-S User's Manual, that RESO usually varies from 2.0 to 6.0 with an "average" value of 3.5. In RESO, a lower number results in lower cost for the same type project, indicating all other factors being equal, the lower the RESO value the better the company probably is at developing software. This parameter is very sensitive; a small change in value shows a large change in cost. Past experience has indicated that for AFAL projects, the "average" value of RESO is too high, so values lower than 3.5 were chosen for projects. Specifically, for Project A, a RESO of 2.7 was chosen because the two people working on the software conversion had extensive experience in software. For Project B, 3.15 was chosen for RESO because the individual performing the project did not have extensive experience in software coding. For Project C and D, RESO was chosen to be 2.7 and 2.5 respectively, as both contractors had experience in the type project on which they were working. All chosen values were agreed upon by the AAA-3 analyst and appropriate RWA personnel.

4. FUNCT, STRU, LEVEL - These three parameters are used with HIPO charts: FUNCT is the total number of functional modules planned for software development; LEVEL is the average level of work breakdown structure in a HIPO table of contents, and STRU is an empirical value that relates LEVEL to FUNCT. None of these parameters are necessary for PRICE-S inputs, however, they can be useful as cross-check values.

TABLE 1

INSTRUCTION MIX

APPLICATION TYPE	WEIGHT	IDENTIFYING CHARACTERISTICS
OPERATING SYSTEMS (-OPR)	10.95	Task mangement. Memory management. Heavy hardware interface. Many interactions. High reliability and strict timing requirements.
INTERACTIVE OPERATIONS (-INT)	10.95	Real time man/machine interfaces. Human engineering considerations and error protection very important.
REAL TIME COMMAND AND CONTROL (-REA)	8.46	Machine to machine communications under tight timing constraints. Queuing not practicable. Heavy hardware interface. Strict protocol requirements.
ON-LINE COMMUNICATIONS (-ONL)	6.16	Machine to machine communications with queuing allowed. Timing restrictions not as restrictive as with real time command and control.
DATA STORAGE AND RETRIEVAL (-DAT)	4.10	Operation of data storage devices. Data base management. Secondary storage handling. Data blocking and de-blocking. Hashing techniques. Hardware oriented.
STRING MANIPULATION (-STR)	2.31	Routine applications with no overriding constraints. Not oriented toward mathematics. Typified by language compilers, sorting, formatting, buffer manipulation, etc.
MATHEMATICAL OPERATIONS (-MAT)	.86	Routine mathematical applications with no overriding constraints.

They were not specified for any of the four projects in this study.

5. INTEG - This parameter integrates the level of integration and test required to combine a program into the overall package. INTEG can vary between 0 and 1, with .5 being "typical." For Projects A, B and D, which were "stand alone" packages, no integration was needed, and INTEG=0 was input for Project C, two packages had to have some interaction. Since the integration was not complex, INTEG=.3 was chosen for both packages.

6. MIX - (MDAT, etc.) These seven parameters define the software profile in terms of functional applications as outlined in Table 1. For each of the four projects, the mix was given in input data. The optional parameters MAPP and APPL 8 were not used since these parameters represent special categories not needed for these projects.

7. NEW DESIGN - (DDAT, etc.) This is the fraction of each mix category (see Table 1) that requires new design. A value of "1" indicates 100% new design. All values for this category were obtained directly from RWA data.

8. NEW CODE - (CDAT, etc.) This is the fraction of each mix category (see Table 1) that requires new code. In some cases, where recording is done to an existing program, NEW CODE may have a greater value than NEW DESIGN. For all projects, values for NEW CODE were taken directly from input data.

9. DEVICE TYPES - (TDAT, etc.) This is the number of unique hardware devices in each of four categories (see Table 1) for the program. These values have no effect on cost and are used for cross-checking only. For all projects, the device types, when input, were obtained directly from RWA input data.

10. DEVICE QUANTITIES - (QDAT, etc.) This is the total number of hardware devices in each of four categories (see Table 1) for the program. Like types (see #9), these values have no effect on cost and are used for cross-checking only. For all projects, these values, when input, were obtained directly from RWA input data.

11. CPLX - This is a measure of the complexity of the program which relates the difficulty of a task to the normal time needed for accomplishment. Table 2 outlines an RCA method for computing CPLX, with CPLX for a "normal new project" with a "normal crew" having a value of 1.0. Using Table 2 and information about each software program, CPLX was input as follows:

For Project A, a CPLX value of 1.0 was chosen, as the project was considered a "normal" new project with an experienced crew. For Project B, a CPLX value of 0.9 was chosen, as the project was considered a redo of previous work, but done with some new hires. For Project C, a value of 1.0 was chosen, as the project appeared "normal" in all respects. For Project D, a value of .9 was chosen because of the experience level of the personnel.

TABLE 2

TYPICAL CPLX VALUES

"Normal" = 1.0

Typical Complexity Adjustments	
Personnel	ΔCPLX
Outstanding crew, among best in industry	–.2
Extensive experience, some top talent	–.1
Normal crew, experienced	0
Mixed experience, some new hires	+.1
Relatively inexperienced, many new hires	+.2
Product Familiarity	
Old hat, redo of previous work	–.2
Familiar type of project	–.1
Normal new project, normal line of business	0
New line of business	+.2
Complicating Factors	
New hardware	+.1
New language	+.1
More than one location/organization	+.2
Hardware developed in parallel	+.3
Many changing requirements	+.3
State-of-art advancement	+.4 to +.6

TABLE 3

TYPICAL PLATFORM VALUES

Operating Environment	PLTFM
Production Center – Internally Developed Software	0.8
Production Center – Contracted Software	1.0
Military Mobile (Van or Shipboard)	1.4
Commercial Avionics	1.7
MIL-Spec Avionics	1.8
Unmanned Space	2.0
Manned Space	2.5

12. SCHEDULE DATA - This consists of the schedule milestones for a project, including Design Phase Start and End dates (DSTART, DEND), Implementation Phase Start and End dates ISTART, IEND), and Test and Integration Start and End dates (TSTART and TEND). For all four projects, the month and year for DSTART and TEND were specified; the intermediate milestones were not specified.

NOTE: For all PRICE-S runs, DSTART must be specified along with either CPLX or TEND. If only DSTART and CPLX are specified, all other schedule milestones will be computed by PRICE-S; if only DSTART and TEND are specified, PRICE-S will compute a CPLX value and all intermediate milestones.

13. YEAR - This parameter defines the baseline year for technology improvement and for cost escalation. For all projects, the year of the start of the project was selected.

14. ESC - This parameter defines how cost escalation will be computed. A value of "1" used here for all projects lets the model calculate cost escalation based on an internal rate table containing the following rates:

5.5% for 1973	7.9% for 1978
6.7% for 1974	8.7% for 1979
9.7% for 1975	9.6% for 1980
8.0% for 1976	9.1% for 1981
7.6% for 1977	

15. TECIMP - This parameter defines the level of software technology improvement from January 1 of YEAR to DSTART. No technological improvement was assumed for any of the projects, so TECIMP=0 was input for all projects.

16. MULT - This is a linear multiplying factor for all project costs which is used for fee and "G&A." For Projects A and B, done in-house, MULT=1000 was selected, which does not add any overhead, but lists outputs to the nearest dollar. For Projects C and D, contracted efforts, MULT was input to reflect fees.

17. PLTFM - This parameter relates the cost of software development to the environment in which it must operate; it is a measure of software testing and reliability requirements that must be met. Table 3 lists typical PLTFM values. For Projects A, D and Airborne portion of C, a PLTFM value of 1.7, "Commercial Avionics," was selected. The software for these projects was designed for airborne applications, but no formal testing or military specifications were required during development. For Projects B and the Simulator portion of Project C, a PLTFM value of 1.0 was selected because these projects were designed for fixed ground applications.

18. UTIL - This parameter refers to the fraction of available hardware speed and memory capacity utilized by a program, whichever is greater. Values of UTIL below .5 indicate no constraints and do not affect cost,

but values above .5 and especially above .8, have significant cost impact. For Project D and for the Airborne portion of Project C, memory constraints resulted in high UTIL values of .80 and .85, respectively. For other projects, values of .5 or less were selected for UTIL, as no severe constraints were present.

19. TARCST - The actual cost of the project used in the "ECIRP" or "Design to Cost" modes of PRICE-S. This was not specified for any of the projects, as all runs were made in the "normal" mode.

PRICE Software Model Input Worksheet

Filename: ____

Page 1 of 1

								Optional	
Title	PROJECT "A"								
Application	IN-HOUSE SOFTWARE CONVERSION								
Date	7 Feb 78								
Descriptors	INST	APPL	RESO	FUNCT	STRU	LEVEL		INTEG	
	18000	0	2.7	0	0	0			
Mix	MDAT	MONL	MREA	MINT	MMAT	MSTR	MOPR	MAPP	APPL
	.07	0	.17	.07	.33	.03	.33		
New Design	DDAT	DONL	DREA	DINT	DMAT	DSTR	DOPR	DAPP	
	.001	.001	1	1	.6	.001	1		
New Code	CDAT	CONL	CREA	CINT	CMAT	CSTR	COPR	CAPP	
	1	.001	1	1	1	1	1		
Device Types	TDAT	TONL	TREA	TINT					
	1	1	3	1					
Quantity	QDAT	QONL	QREA	QINT					
	1	1	3	1					
Schedule Data	CPLX	DSTART	DEND	ISTART	IEND	TSTART	TEND		
	1.0	0573	0	0	0	0	1275		
Supplementary Information	YEAR	ESC	TECIMP	MULT	PLTFM	UTIL		TARCST	
	1973	1	0	1000	1.7	.5			

Notes:

PRICE Software Model Input Worksheet

Filename:

Page 1 of 1

Title: PROJECT "B"

Application: IN-HOUSE SIMULATOR

Date: 13 Feb 78

								Optional	
Descriptors	INST	APPL	RESO	FUNCT	STRU	LEVEL		INTEG	
	2600	0	3.15	0	0	0			
Mix	MDAT	MONL	MREA	MINT	MMAT	MSTR	MOPR	MAPP	APPL
	0	0	0	.05	.95	0	0		
New Design	DDAT	DONL	DREA	DINT	DMAT	DSTR	DOPR	DAPP	
	.001	.001	.001	1	.1	.001	.001		
New Code	CDAT	CONL	CREA	CINT	CMAT	CSTR	COPR	CAPP	
	.001	.001	.001	1	1	.001	.001		
Device Types	TDAT	TONL	TREA	TINT					
	1	1	0	1					
Quantity	QDAT	QONL	QREA	QINT					
	1	1	0	1					
Schedule Data	CPLX	DSTART	DEND	ISTART	IEND	TSTART	TEND		
	.9	1177	0	0	0	0	0278		
Supplementary Information	YEAR	ESC	TECIMP	MULT	PLTFM	UTIL		TARCST	
	1977	1	0	1000	1.0	.3			

Notes:

PRICE Software Model Input Worksheet

Filename: ______

Title PROJECT "C"

Application CONTRACTED ANTENNA: AIRBORNE SOFTWARE

Date 20 Mar 78

								Optional	
Descriptors	INST	APPL	RESO	FUNCT	STRU	LEVEL		INTEG	
	2000	0	2.7	0	0	0		.3	
Mix	MDAT	MONL	MREA	MINT	MMAT	MSTR	MOPR	MAPP	APPL
	.1	.1	.8	0	0	0	0		
New Design	DDAT	DONL	DREA	DINT	DMAT	DSTR	DOPR	DAPP	
	.25	.25	.25	0	0	0	0		
New Code	CDAT	CONL	CREA	CINT	CMAT	CSTR	COPR	CAPP	
	1	1	1	0	0	0	0		
Device Types	TDAT	TONL	TREA	TINT					
	0	0	0	0					
Quantity	QDAT	QONL	QREA	QINT					
	0	0	0	0					
Schedule Data	CPLX	DSTART	DEND	ISTART	IEND	TSTART	TEND		
	1.0	0578	0	0	0	0	0179		
Supplementary Information	YEAR	ESC	TECIMP	MULT	PLTFM	UTIL		TARCST	
	1978	1	0	1060	1.7	.8			

Notes:

PRICE Software Model Input Worksheet

Filename: ____

Page 2 of 3

Title: PROJECT "C"

Application: CONTRACTED ANTENNA: SIMULATION SOFTWARE

Date: 20 Mar 78

								Optional	
Descriptors	INST	APPL	RESO	FUNCT	STRU	LEVEL		INTEG	
	20000	0	2.7	0	0	0		.3	
Mix	MDAT	MONL	MREA	MINT	MMAT	MSTR	MOPR	MAPP	APPL
	0	0	0	0	.8	0	.2		
New Design	DDAT	DONL	DREA	DINT	DMAT	DSTR	DOPR	DAPP	
	0	0	0	0	.1	0	.1		
New Code	CDAT	CONL	CREA	CINT	CMAT	CSTR	COPR	CAPP	
	0	0	0	0	.1	0	.1		
Device Types	TDAT	TONL	TREA	TINT					
	0	0	0	0					
Quantity	QDAT	QONL	QREA	QINT					
	0	0	0	0					
Schedule Data	CPLX	DSTART	DEND	ISTART	IEND	TSTART	TEND		
	1.0	0578	0	0	0	0	0179		
Supplementary Information	YEAR	ESC	TECIMP	MULT	PLTFM	UTIL		TARCST	
	1978	1	0	1060	1.0	.2			

Notes:

GC 1610 8/77

MCM

PRICE Software Model Input Worksheet

Filename: ______

Title PROJECT "C"

Application CONTRACTED ANTENNA: SOFTWARE INTEGRATION AND TEST

Date 20 Mar 78

								Optional	
Descriptors	INST	APPL	RESO	FUNCT	STRU	LEVEL		INTEG	
	$								
Mix	MDAT	MONL	MREA	MINT	MMAT	MSTR	MOPR	MAPP	APPL
New Design	DDAT	DONL	DREA	DINT	DMAT	DSTR	DOPR	DAPP	
New Code	CDAT	CONL	CREA	CINT	CMAT	CSTR	COPR	CAPP	
Device Types	TDAT	TONL	TREA	TINT					
Quantity	QDAT	QONL	QREA	QINT					
Schedule Data	CPLX	DSTART	DEND	ISTART	IEND	TSTART	TEND		
	1.0	1078	0	0	0	0	0179		
Supplementary Information	YEAR	ESC	TECIMP	MULT	PLTFM	UTIL		TARCST	
	1978	1	0	1060	1.0	.2			

Notes:

PRICE Software Model Input Worksheet

Filename:

Page 1 of 1

Title: PROJECT "D"

Application: CONTRACTED RADAR

Date: 23 Jun 78

Optional

Descriptors	INST	APPL	RESO	FUNCT	STRU	LEVEL		INTEG
	73750	0	2.5	0	0	0		
Mix	MDAT	MONL	MREA	MINT	MMAT	MSTR	MOPR	MAPP / APPL
	.15	0	.15	.05	.65	0	0	
New Design	DDAT	DONL	DREA	DINT	DMAT	DSTR	DOPR	DAPP
	1	0	1	1	.99	0	0	
New Code	CDAT	CONL	CREA	CINT	CMAT	CSTR	COPR	CAPP
	1	0	1	1	.99	0	0	
Device Types	TDAT	TONL	TREA	TINT				
	4	1	3	1				
Quantity	QDAT	QONL	QREA	QINT				
	4	3	3	1				
Schedule Data	CPLX	DSTART	DEND	ISTART	IEND	TSTART	TEND	
	.9	0574	0	0	0	0	0579	
Supplementary Information	YEAR	ESC	TECIMP	MULT	PLTFM	UTIL		TARCST
	1974	1	0	1120	1.7	.85		

Notes:

APPENDIX B

PRICE-S OUTPUTS

This appendix contains the actual PRICE-S run data and outputs for each of the four projects considered, with total costs circled. The outputs also include a sensitivity analysis which shows the effect of changes for RESO and CPLX on cost, and a schedule effect summary which compares the input schedule to a "typical" schedule computed by PRICE-S and demonstrates areas where cost savings may be realized by changing schedules.

--- PRICE SOFTWARE MODEL ---

DATE 6-MAR-79 TIME 09:02

IN HOUSE SOFTWARE CONVERSION NAV SYSTEM

INPUT DATA

FILENAME: PROJA DATED: 7 FEB 78

DESCRIPTORS

INSTRUCTIONS	18000	APPLICATION	0.000	RESOURCE	2.700
FUNCTIONS	0	STRUCTURE	0.000	LEVEL	0.000

APPLICATION CATEGORIES		NEW DEVELOPMENT		SYSTEM CONFIGURATION	
	MIX	DESIGN	CODE	TYPES	QUANTITY
DATA S/R	0.07	0.00	1.00	1	1
ONLINE COMM	0.00	0.00	0.00	1	1
REALTIME C&C	0.17	1.00	1.00	3	3
INTERACTIVE	0.07	1.00	1.00	1	1
MATHEMATICAL	0.33	0.60	1.00	***	***
STRING MANIP	0.03	0.00	1.00	***	***
OPR SYSTEMS	0.33	1.00	1.00	***	***

SCHEDULE

COMPLEXITY	1.000				
DESIGN START	MAY 73	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	DEC 75

SUPPLEMENTAL INFORMATION

YEAR	1973	ESCALATION	1.000	TECH IMP	0.00
MULTIPLIER	1000.000	PLATFORM	1.7	UTILIZATION	0.50

PROGRAM COSTS

COST ELEMENTS	DESIGN	IMPL	T & I	TOTAL
SYSTEMS ENGINEERING	93037.	4845.	84837.	182720.
PROGRAMMING	20096.	26919.	34699.	81713.
CONFIGURATION CONTROL	14811.	7408.	53815.	76033.
DOCUMENTATION	14295.	2451.	23824.	40570.
PROGRAM MANAGEMENT	11826.	2237.	10936.	24999.
TOTAL	154065.	43860.	208110.	406035.

ADDITIONAL DATA

DESCRIPTORS

INSTRUCTIONS	18000	APPLICATION	6.461	RESOURCE	2.700
FUNCTIONS	200	STRUCTURE	0.000	LEVEL	0.000

SCHEDULE

COMPLEXITY	1.000				
DESIGN START	MAY 73	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	DEC 75

--- PRICE SOFTWARE MODEL ---

DATE 6-MAR-79 TIME 09:04

N HOUSE SOFTWARE CONVERSION NAV SYSTEM

SENSITIVITY DATA

RESOURCE	COMPLEXITY .900	COMPLEXITY 1.000	COMPLEXITY 1.100
2.600	COST 378315. MONTHS 31.0	COST 386101. MONTHS 31.0	COST 397826. MONTHS 31.0
2.700	COST 397675. MONTHS 31.0	COST 406035. MONTHS 31.0	COST 418577. MONTHS 31.0
2.800	COST 418788. MONTHS 31.0	COST 427777. MONTHS 31.0	COST 441212. MONTHS 31.0

SCHEDULE EFFECT SUMMARY

ACTIVITY LENGTH IN MONTHS

COMPLEXITY = 1.000	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE (OVERLAP)	0.0	(0.0) 0.0	(0.0) 0.0	31.0
TYPICAL SCHEDULE (OVERLAP)	7.1	(4.2) 7.7	(4.6) 11.0	17.0

DEVELOPMENT COSTS

COMPLEXITY = 1.000	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	154065.	43860.	208110.	406035.
TYPICAL SCHEDULE	127715.	36295.	170634.	334644.
ESTIMATED PENALTY	26350.	7565.	37477.	71391.

--- PRICE SOFTWARE MODEL ---

DATE 6-MAR-79 TIME 09:08

IN HOUSE SIMULATOR NAV SYSTEM

INPUT DATA

FILENAME: PROJB DATED: 13 FEB 78

DESCRIPTORS					
INSTRUCTIONS	2600	APPLICATION	0.000	RESOURCE	3.150
FUNCTIONS	0	STRUCTURE	0.000	LEVEL	0.000

APPLICATION CATEGORIES	MIX	NEW DEVELOPMENT DESIGN	CODE	SYSTEM CONFIGURATION TYPES	QUANTITY
DATA S/R	0.00	0.00	0.00	1	1
ONLINE COMM	0.00	0.00	0.00	1	1
REALTIME C&C	0.00	0.00	0.00	0	0
INTERACTIVE	0.05	1.00	1.00	1	1
MATHEMATICAL	0.95	0.10	1.00	***	***
STRING MANIP	0.00	0.00	0.00	***	***
OPR SYSTEMS	0.00	0.00	0.00	***	***

SCHEDULE					
COMPLEXITY	0.900				
DESIGN START	NOV 77	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	FEB 78

SUPPLEMENTAL INFORMATION					
YEAR	1977	ESCALATION	1.000	TECH IMP	0.00
MULTIPLIER	1000.000	PLATFORM	1.0	UTILIZATION	0.30

PROGRAM COSTS

COST ELEMENTS	DESIGN	IMPL	T & I	TOTAL
SYSTEMS ENGINEERING	2267.	190.	3571.	6028.
? PROGRAMMING	620.	1140.	1460.	3220.
CONFIGURATION CONTROL	182.	181.	1372.	1734.
DOCUMENTATION	143.	42.	409.	594.
PROGRAM MANAGEMENT	185.	48.	229.	462.
TOTAL	3397.	1601.	7041.	12039.

ADDITIONAL DATA

DESCRIPTORS					
INSTRUCTIONS	2600	APPLICATION	1.370	RESOURCE	3.150
FUNCTIONS	29	STRUCTURE	0.000	LEVEL	0.000

SCHEDULE					
COMPLEXITY	0.900				
DESIGN START	NOV 77	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	FEB 78

--- PRICE SOFTWARE MODEL ---

DATE 6-MAR-79 TIME 09:10

HOUSE SIMULATOR NAV SYSTEM

SENSITIVITY DATA

		COMPLEXITY .800		COMPLEXITY .900		COMPLEXITY 1.000	
RESOURCE 3.050		COST	11641.	COST	11632.	COST	11719.
		MONTHS	3.0	MONTHS	3.0	MONTHS	3.0
RESOURCE 3.150		COST	12045.	COST	12039.	COST	12131.
		MONTHS	3.0	MONTHS	3.0	MONTHS	3.0
RESOURCE 3.250		COST	12381.	COST	12376.	COST	12473.
		MONTHS	3.0	MONTHS	3.0	MONTHS	3.0

SCHEDULE EFFECT SUMMARY

ACTIVITY LENGTH IN MONTHS

COMPLEXITY = 0.900	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	0.0	0.0	0.0	3.0
(OVERLAP)	(0.0)	(0.0)		
TYPICAL SCHEDULE	0.8	0.7	1.1	2.1
(OVERLAP)	(0.2)	(0.2)		

DEVELOPMENT COSTS

COMPLEXITY = 0.900	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	3397.	1601.	7041.	12039.
TYPICAL SCHEDULE	3302.	1575.	6921.	11797.
ESTIMATED PENALTY	95.	26.	120.	241.

--- PRICE SOFTWARE MODEL ---

DATE 8-MAR-79 TIME 07:38

CONTRACTED ANTENNA AIRBORNE SOFTWARE

INPUT DATA

FILENAME: PROJC DATED: 20 MARCH 78

DESCRIPTORS					
INSTRUCTIONS	2000	APPLICATION	0.000	RESOURCE	2.700
FUNCTIONS	0	STRUCTURE	0.000	LEVEL	0.000
				INTEGRATION	0.300

APPLICATION CATEGORIES		NEW DEVELOPMENT		SYSTEM CONFIGURATION	
	MIX	DESIGN	CODE	TYPES	QUANTITY
DATA S/R	0.10	0.25	1.00	0	0
ONLINE COMM	0.10	0.25	1.00	0	0
REALTIME C&C	0.80	0.25	1.00	0	0
INTERACTIVE	0.00	1.00	1.00	0	0
MATHEMATICAL	0.00	1.00	1.00	***	***
STRING MANIP	0.00	1.00	1.00	***	***
OPR SYSTEMS	0.00	1.00	1.00	***	***

SCHEDULE					
COMPLEXITY	1.000				
DESIGN START	MAY 78	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	JAN 79

SUPPLEMENTAL INFORMATION					
YEAR	1978	ESCALATION	1.000	TECH IMP	0.00
MULTIPLIER	1060.000	PLATFORM	1.7	UTILIZATION	0.80

PROGRAM COSTS

COST ELEMENTS	DESIGN	IMPL	T & I	TOTAL
SYSTEMS ENGINEERING	11424.	882.	18457.	30763.
PROGRAMMING	2468.	4901.	7549.	14917.
CONFIGURATION CONTROL	1384.	1027.	8912.	11323.
DOCUMENTATION	1299.	324.	3653.	5276.
PROGRAM MANAGEMENT	1049.	292.	1628.	2969.
TOTAL	17624.	7426.	40199.	65249.

ADDITIONAL DATA

DESCRIPTORS					
INSTRUCTIONS	2000	APPLICATION	7.795	RESOURCE	2.700
FUNCTIONS	22	STRUCTURE	0.000	LEVEL	0.000

SCHEDULE					
COMPLEXITY	1.000				
DESIGN START	MAY 78	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	JAN 79

--- PRICE SOFTWARE MODEL ---

DATE 8-MAR-79 TIME 07:40

CONTRACTED ANTENNA AIRBORNE SOFTWARE

SENSITIVITY DATA

RESOURCE		COMPLEXITY .900		COMPLEXITY 1.000		COMPLEXITY 1.100	
2.600	COST	59365.	COST	62232.	COST	66002.
	MONTHS	8.0	MONTHS	8.0	MONTHS	8.0
2.700	COST	62190.	COST	65249.	COST	69269.
	MONTHS	8.0	MONTHS	8.0	MONTHS	8.0
2.800	COST	64633.	COST	67868.	COST	72114.
	MONTHS	8.0	MONTHS	8.0	MONTHS	8.0

SCHEDULE EFFECT SUMMARY

ACTIVITY LENGTH IN MONTHS

COMPLEXITY = 1.000	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	0.0	0.0	0.0	8.0
(OVERLAP)		(0.0)	(0.0)	
TYPICAL SCHEDULE	2.4	3.1	4.8	7.0
(OVERLAP)		(1.4)	(1.8)	

DEVELOPMENT COSTS

COMPLEXITY = 1.000	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	17624.	7426.	40199.	65249.
TYPICAL SCHEDULE	17463.	7357.	39816.	64636.
ESTIMATED PENALTY	161.	69.	383.	613.

--- PRICE SOFTWARE MODEL ---

DATE 8-MAR-79 TIME 07:42

CONTRACTED ANTENNA SIMULATION SOFTWARE

INPUT DATA

FILENAME: PROJC DATED: 20 MARCH 78

DESCRIPTORS

INSTRUCTIONS	20000	APPLICATION	0.000	RESOURCE	2.700
FUNCTIONS	0	STRUCTURE	0.000	LEVEL	0.000
				INTEGRATION	0.300

APPLICATION CATEGORIES		NEW DEVELOPMENT		SYSTEM CONFIGURATION	
	MIX	DESIGN	CODE	TYPES	QUANTITY
DATA S/R	0.00	1.00	1.00	0	0
ONLINE COMM	0.00	1.00	1.00	0	0
REALTIME C&C	0.00	1.00	1.00	0	0
INTERACTIVE	0.00	1.00	1.00	0	0
MATHEMATICAL	0.80	0.10	0.10	***	***
STRING MANIP	0.00	1.00	1.00	***	***
OPR SYSTEMS	0.20	0.10	0.10	***	***

SCHEDULE

COMPLEXITY	1.000				
DESIGN START	MAY 78	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	JAN 79

SUPPLEMENTAL INFORMATION

YEAR	1978	ESCALATION	1.000	TECH IMP	0.00
MULTIPLIER	1060.000	PLATFORM	1.0	UTILIZATION	0.20

PROGRAM COSTS

COST ELEMENTS	DESIGN	IMPL	T & I	TOTAL
SYSTEMS ENGINEERING	11213.	552.	22238.	34003.
PROGRAMMING	2422.	3065.	9095.	14582.
CONFIGURATION CONTROL	1385.	654.	10943.	12982.
DOCUMENTATION	998.	159.	3457.	4614.
PROGRAM MANAGEMENT	1033.	185.	1968.	3185.
TOTAL	17051.	4614.	47701.	69366.

ADDITIONAL DATA

DESCRIPTORS

INSTRUCTIONS	20000	APPLICATION	2.883	RESOURCE	2.700
FUNCTIONS	222	STRUCTURE	0.000	LEVEL	0.000

SCHEDULE

COMPLEXITY	1.000				
DESIGN START	MAY 78	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	JAN 79

--- PRICE SOFTWARE MODEL ---

DATE 8-MAR-79 TIME 07:44

CONTRACTED ANTENNA SIMULATION SOFTWARE

SENSITIVITY DATA

RESOURCE	COMPLEXITY .900	COMPLEXITY 1.000	COMPLEXITY 1.100
2.600	COST 65014. MONTHS 8.0	COST 66153. MONTHS 8.0	COST 67801. MONTHS 8.0
2.700	COST 68145. MONTHS 8.0	COST 69366. MONTHS 8.0	COST 71126. MONTHS 8.0
2.800	COST 70840. MONTHS 8.0	COST 72136. MONTHS 8.0	COST 73997. MONTHS 8.0

SCHEDULE EFFECT SUMMARY

ACTIVITY LENGTH IN MONTHS

COMPLEXITY = 1.000	DESIGN		IMPL		T & I	TOTAL
SPECIFIED SCHEDULE	0.0		0.0		0.0	8.0
(OVERLAP)		(0.0)		(0.0)		
TYPICAL SCHEDULE	1.8		1.5		3.1	5.3
(OVERLAP)		(0.6)		(0.5)		

DEVELOPMENT COSTS

COMPLEXITY = 1.000	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	17051.	4614.	47701.	69366.
TYPICAL SCHEDULE	15981.	4321.	44587.	64889.
ESTIMATED PENALTY	1070.	293.	3114.	4478.

--- PRICE SOFTWARE MODEL ---

SYSTEM INTEGRATION

DATE 8-MAR-79 TIME 07:47

CONTRACTED ANTENNA INTEGRATION AND TEST

INPUT DATA

FILENAME: PROJC DATED: 20 MARCH 78

SCHEDULE

COMPLEXITY	1.000				
DESIGN START	OCT 78	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	JAN 79

SUPPLEMENTAL INFORMATION

YEAR	1978	ESCALATION	1.000	TECH IMP	0.00
MULTIPLIER	1060.000	PLATFORM	1.0	UTILIZATION	0.20

PROGRAM COSTS

COST ELEMENTS	DESIGN	IMPL	T & I	TOTAL
SYSTEMS ENGINEERING	2740.	134.	2265.	5139.
PROGRAMMING	592.	745.	927.	2264.
CONFIGURATION CONTROL	219.	103.	723.	1046.
DOCUMENTATION	153.	24.	208.	384.
PROGRAM MANAGEMENT	155.	27.	115.	297.
TOTAL	3859.	1034.	4238.	9130.

ADDITIONAL DATA

SCHEDULE

COMPLEXITY	1.000				
DESIGN START	OCT 78	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	JAN 79

SUMMARY OF SOFTWARE DEVELOPMENT TOTALS

PROGRAM COSTS

COST ELEMENTS	DESIGN	IMPL	T & I	TOTAL
SYSTEMS ENGINEERING	25377.	1568.	42960.	69905.
PROGRAMMING	5481.	8711.	17571.	31763.
CONFIGURATION CONTROL	2988.	1784.	20578.	25350.
DOCUMENTATION	2451.	507.	7317.	10275.
PROGRAM MANAGEMENT	2237.	504.	3711.	6452.
TOTAL	38534.	13074.	92138.	143746.

--- PRICE SOFTWARE MODEL ---

SYSTEM INTEGRATION

DATE 8-MAR-79 TIME 07:49

CONTRACTED ANTENNA INTEGRATION AND TEST

SENSITIVITY DATA

RESOURCE		COMPLEXITY .900		COMPLEXITY 1.000		COMPLEXITY 1.100	
2.600	COST	8617.	COST	8771.	COST	9028.	
	MONTHS	3.0	MONTHS	3.0	MONTHS	3.0	
2.700	COST	8966.	COST	9130.	COST	9404.	
	MONTHS	3.0	MONTHS	3.0	MONTHS	3.0	
2.800	COST	9265.	COST	9439.	COST	9728.	
	MONTHS	3.0	MONTHS	3.0	MONTHS	3.0	

SCHEDULE EFFECT SUMMARY

ACTIVITY LENGTH IN MONTHS

COMPLEXITY = 1.000	DESIGN		IMPL		T & I	TOTAL
SPECIFIED SCHEDULE	0.0		0.0		0.0	3.0
(OVERLAP)		(0.0)		(0.0)		
TYPICAL SCHEDULE	1.0		0.8		1.2	2.4
(OVERLAP)		(0.4)		(0.3)		

DEVELOPMENT COSTS

COMPLEXITY = 1.000	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	3859.	1034.	4238.	9130.
TYPICAL SCHEDULE	3788.	1015.	4160.	8962.
ESTIMATED PENALTY	71.	19.	78.	168.

--- PRICE SOFTWARE MODEL ---

DATE 6-MAR-79 TIME 09:27

CONTRACTED RADAR RADAR SOFTWARE

INPUT DATA

FILENAME: PROJD DATED: 23 JUNE 78

DESCRIPTORS					
INSTRUCTIONS	73750	APPLICATION	0.000	RESOURCE	2.500
FUNCTIONS	0	STRUCTURE	0.000	LEVEL	0.000

APPLICATION CATEGORIES	MIX	NEW DEVELOPMENT DESIGN	CODE	SYSTEM CONFIGURATION TYPES	QUANTITY
DATA S/R	0.15	1.00	1.00	4	4
ONLINE COMM	0.00	0.00	0.00	1	3
REALTIME C&C	0.15	1.00	1.00	3	3
INTERACTIVE	0.05	1.00	1.00	1	1
MATHEMATICAL	0.65	0.99	0.99	***	***
STRING MANIP	0.00	0.00	0.00	***	***
OPR SYSTEMS	0.00	0.00	0.00	***	***

SCHEDULE					
COMPLEXITY	0.900				
DESIGN START	MAY 74	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	MAY 79

SUPPLEMENTAL INFORMATION					
YEAR	1974	ESCALATION	1.000	TECH IMP	0.00
MULTIPLIER	1120.000	PLATFORM	1.7	UTILIZATION	0.85

PROGRAM COSTS

COST ELEMENTS	DESIGN	IMPL	T & I	TOTAL
SYSTEMS ENGINEERING	406400.	14914.	388455.	809769.
PROGRAMMING	111149.	89289.	158878.	359316.
CONFIGURATION CONTROL	61983.	26983.	284174.	373139
DOCUMENTATION	67209.	9057.	131790.	208056.
PROGRAM MANAGEMENT	70744.	8280.	61617.	140641.
TOTAL	717485.	148523.	1024914.	1890922

ADDITIONAL DATA

DESCRIPTORS					
INSTRUCTIONS	73750	APPLICATION	2.997	RESOURCE	2.500
FUNCTIONS	819	STRUCTURE	0.000	LEVEL	0.000

SCHEDULE					
COMPLEXITY	0.900				
DESIGN START	MAY 74	IMPL START	0	T&I START	0
DESIGN END	0	IMPL END	0	T&I END	MAY 79

--- PRICE SOFTWARE MODEL ---

DATE 6-MAR-79 TIME 09:29

NTRACTED RADAR RADAR SOFTWARE

SENSITIVITY DATA

RESOURCE \ COMPLEXITY	.800	.900	1.000
2.400	COST 1783797. MONTHS 60.0	COST 1780101. MONTHS 60.0	COST 1794730. MONTHS 60.0
2.500	COST 1894502. MONTHS 60.0	COST 1890922. MONTHS 60.0	COST 1906885. MONTHS 60.0
2.600	COST 2007339. MONTHS 60.0	COST 2003904. MONTHS 60.0	COST 2021260. MONTHS 60.0

SCHEDULE EFFECT SUMMARY

ACTIVITY LENGTH IN MONTHS

COMPLEXITY = 0.900	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	0.0	0.0	0.0	60.0
(OVERLAP)	(0.0)	(0.0)		
TYPICAL SCHEDULE	8.6	9.2	13.1	20.8
(OVERLAP)	(4.9)	(5.2)		

DEVELOPMENT COSTS

COMPLEXITY = 0.900	DESIGN	IMPL	T & I	TOTAL
SPECIFIED SCHEDULE	717485.	148523.	1024914.	1890922.
TYPICAL SCHEDULE	468313.	93945.	628006.	1190265.
ESTIMATED PENALTY	249172.	54578.	396908.	700657.

REFERENCES

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